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The Hypothesis of Field-Induced Destruction of Quantum Space Self-Organization as an Explanation for the Late Acceleration of the Universe

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Abstract

The standard cosmological model (ΛCDM) describes dark energy (DE) as a cosmological constant but fails to answer the coincidence problem: why did the accelerated expansion of the Universe begin precisely ~7 billion years ago? Screening models (Chameleon, Symmetron) address the problem of DE's local invisibility but also do not explain the temporal transition. We propose a new hypothesis: DE is a macroscopic manifestation of the self-organization process of space quanta into an ordered structure, a process that is destroyed in the presence of gravitational and electromagnetic fields. The transition at ~7 billion years is interpreted as the moment when the average field strength in the Universe fell below a critical threshold, allowing the self-organization of quanta to begin. The hypothesis predicts a strong contrast in DE density between cosmic voids and dense environments, as well as the strict absence of DE in laboratory conditions, distinguishing it from existing screening models and opening the way for observational verification with the Euclid mission. We also show that the hypothesis does not contradict inflationary cosmology, offering two possible reconciliation options: the standard inflaton scenario and, as a more radical alternative, a scenario of inverted space birth.

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1. Introduction

The ΛCDM cosmological model successfully describes the evolution of the Universe but contains two unresolved conceptual questions related to dark energy:

1. **The Coincidence Problem:** The density of DE (denoted as ρΛ) is approximately 10^(-29) g/cm³, comparable to the current matter density, yet lacks an obvious physical reason to be so. In the ΛCDM framework, the onset of acceleration (~7 billion years ago) is a random coincidence.
2. **The Local Invisibility Problem:** DE, being omnipresent, does not manifest itself in laboratory experiments and does not affect the dynamics of bound systems (Solar System, atoms).

Screening models (Chameleon [1], Symmetron [2]) solve the second problem by introducing a scalar field whose properties depend on the density of the environment. However, the coincidence problem remains open within them.

We propose a paradigm shift: to consider DE not as a constantly present field, but as a process whose intensity is determined by the local field background. Certain elements of this idea—the discrete nature of space and the influence of matter on the vacuum—have been discussed in the context of quantum gravity [3], but their synthesis into a single criterion for the field-induced destruction of space quanta self-organization with concrete observational predictions is novel.

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2. Formulation of the Hypothesis

2.1. Three Postulates

Postulate 1: The Nature of DE. Dark energy is a macroscopic manifestation of the quantum-gravitational process of self-organization of space-time quanta into an ordered structure. The density of DE, ρΛ, is proportional to the rate of this process.

Postulate 2: Field-Induced Destruction of Self-Organization. Space quanta possess a fundamental ability for self-organization: in the absence of external influences, they tend to arrange themselves into an ordered structure, which is perceived macroscopically as the birth of a new volume of space-time. However, in the presence of strong gravitational and electromagnetic fields, this structure is destroyed: fields introduce fluctuations sufficient to disrupt the quanta from ordering themselves. A critical threshold, Φcrit, exists such that for $\Phi > \Phi_{crit}$, self-organization is impossible. This postulate is fundamentally different from the Chameleon mechanism: there, the field is masked by changing its effective mass; here, the very process of geometry formation is absent.

Postulate 3: The Destruction Criterion. The field destruction parameter Φ is determined by a linear combination of gravitational and electromagnetic contributions:

$$\Phi(x) = R + k \cdot F^2$$

where R is the scalar curvature (a measure of the gravitational field), F^2 is the squared tensor of the electromagnetic field (a measure of its intensity), and k is a coupling constant. Self-organization is possible only when $\Phi(x) < \Phi_{crit}$.

The inclusion of the electromagnetic field in the destruction criterion is a distinguishing feature of this hypothesis. Since the strong interaction is confined to a scale of 10^(-15) m, which is 20 orders of magnitude larger than the Planck length, its influence on space quanta is considered negligible.

2.2. Compatibility with Established Physics

The hypothesis does not contradict established theories:

- **Quantum Electrodynamics:** The destruction of the forming structure of new space does not alter the geometry of existing space; therefore, atomic spectra and other QED predictions are unaffected.
- **General Relativity:** The hypothesis supplements GR at the micro-level, analogous to how molecular theory supplements thermodynamics. Einstein's equations remain the macroscopic limit.
- **Thermodynamics:** As it concerns the impossibility of structure formation, not the annihilation of existing space, the law of energy conservation is not violated.

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3. Cosmological Solution to the Coincidence Problem

In the early Universe (t < 7 billion years), the average field strength was high: $\langle\Phi\rangle$ significantly exceeded Φ_{crit}. The self-organization of quanta was globally impossible, the effective density of DE was zero, and expansion was decelerating.

As the Universe expanded and cooled, the average field strength decreased. At t ≈ 7 billion years, it crossed the critical threshold, and the destruction ceased. From that moment, the self-organization of space quanta began, perceived as accelerated expansion.

Standard cosmology indicates that 7 billion years ago (z ≈ 0.7), the average matter density was about 5 times higher than today, and radiation density was 8 times higher. This was the end of the so-called "cosmic noon"—the epoch of maximum star formation rate and, consequently, the maximum electromagnetic radiation density in the history of the post-recombination Universe. It was during this period that deep cosmic voids began to form, where $R \to 0$ and $F^2 \to 0$. Thus, the crossing of the Φ_{crit} threshold is not an arbitrary coincidence: it occurred when expansion first created vast regions of space with field strengths below critical, allowing quanta to begin self-organizing. This scenario aligns with the observed picture of the "cosmic noon" and the subsequent decline in star formation.

The modified Friedmann equation takes the form:

$$H^2 = (8\pi G / 3) \times [\rho_m + \rho_\Lambda \times \Theta(\Phi_{crit} - \langle\Phi\rangle)]$$

where Θ is the Heaviside step function ($\Theta = 0$ when the argument is negative, and $\Theta = 1$ when positive). In a more realistic model, the step could be replaced by a sigmoid with a steepness parameter κ, reflecting the "sharpness" of the phase transition.

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4. Inflationary Stage: Two Options for Reconciliation

Inflationary cosmology states that in the first 10^(-35) seconds, the Universe expanded exponentially. At first glance, this contradicts our hypothesis: if fields destroy the self-organization of space, how could inflation occur given the colossal densities of the early Universe? We propose two options for reconciliation.

4.1. Option A (Standard): Inflation as a Separate Process

The first, more conservative option assumes that inflation and late acceleration are two fundamentally different physical processes:

- **Inflation** (t ~ 10^(-35) s) was driven by a scalar field—the inflaton—which is unrelated to the mechanism of space quanta self-organization. The inflaton created exponential expansion due to its potential, as described in standard models [8, 9]. At this time, our proposed mechanism of field-induced destruction was "turned off" due to the ultra-high energies: the rules of quantum gravity in the Planck epoch could be radically different from those that operated later.
- **Late Acceleration** (t ~ 7 billion years) is a completely different stage, when the inflaton had long disappeared and the Universe had cooled enough for our mechanism to activate.

Thus, inflation and dark energy are two independent episodes of expansion with different physical natures. This is a division of labor: inflation created the initial conditions for the hot Big Bang, and dark energy determines the fate of the mature Universe. This option is the safest in terms of compatibility with existing inflationary cosmology and requires no modification of standard inflationary models.

4.2. Option B (Radical): Inverted Space Birth

The second, bolder option considers the possibility that our proposed mechanism has a more universal character. In this scenario, the dependence of space birth on field strength is a non-monotonic function:

Birth Rate = f(Φ)

The behavior of the function f(Φ) in various regimes:

- **For Φ < Φcrit (weak fields, post-7 billion year era):** Birth is allowed and proceeds at a constant rate—the standard regime of our hypothesis, corresponding to observed dark energy.
- **For Φ > Φcrit (moderate fields, 380,000 years – 7 billion year era):** Birth is forbidden, effective DE density is zero.
- **For Φ ≫ Φcrit (super-strong fields, inflationary epoch):** An inversion of the effect occurs. Super-Planckian field strength does not forbid but, on the contrary, stimulates an avalanche-like birth of space—a "vacuum breakdown."

A physical analogy: electrical breakdown in a dielectric. A weak field does not cause breakdown, a medium field causes a controlled current, but a very strong field causes an avalanche breakdown. An analogy with phase transitions: water remains liquid with slight cooling, turns to ice at the freezing point, but with super-rapid and deep cooling, it can transition to an amorphous ice state with completely different properties.

In this option, inflation and late acceleration are two regimes of the same fundamental process. This approach is elegant but requires substantial theoretical development and is beyond the scope of this article. We mention it as a direction for future research.

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5. Local Physics and Observational Predictions

Unlike ΛCDM, where ρΛ is constant, the hypothesis predicts a sharp dependence of the local ability of quanta to self-organize on the field background. This dependence can be parameterized by a sigmoid function:

$$\rho\Lambda(x) = \rho\Lambda 0 / [1 + \exp(-\kappa \times (\Phi crit - \Phi(x)))]$$

where κ is a parameter for the steepness of the transition from destroyed to active self-organization.

5.1. Four Key Predictions

Prediction 1: DE deficit in galaxy clusters and its excess in voids. In the centers of galaxy clusters, R is large, hence $\Phi > \Phi crit$, and the self-organization of quanta is destroyed, $\rho\Lambda \approx 0$. In cosmic voids, $R \to 0$, and the density of galaxies is low, so $F^2 \to 0$. Consequently, Φ is significantly less than $\Phi crit$, and quanta can self-organize without hindrance, $\rho\Lambda \to \rho\Lambda 0$—the maximum value.

This contrast can be detected through weak gravitational lensing analysis. It is noteworthy that existing lensing anomalies in voids (signal excess) and clusters (slight deficit) have a sign consistent with this prediction, although their statistical significance is currently insufficient (2-3 σ). Future data from the Euclid mission, launched in 2023 [6], will allow this prediction to be tested with high precision.

Prediction 2: Strict absence of DE in laboratory conditions. Inside atoms, F^2 is extremely large, and inside planets and stars, R is large. In both cases, Φ significantly exceeds $\Phi crit$, the self-organization of quanta is destroyed, and $\rho\Lambda = 0$. Unlike Chameleon models, where DE is suppressed by many orders of magnitude but is not zero, this hypothesis predicts an exact zero. Laboratory experiments to search for DE (for example, through anomalies in orbital dynamics) should yield negative results to any achievable precision.

Prediction 3: Sharp activation of DE in the past. Analysis of data from Type Ia supernovae and baryon acoustic oscillations should show that the equation of state of DE, w(z), undergoes a sharp transition from $w = -1$ (at $z < 0.7$) to an effective w indistinguishable from zero DE contribution (at $z > 0.7$). Existing parameterizations of w(z) (e.g., CPL) may be too coarse to detect such a transition.

Prediction 4: Constraint on theories of quantum gravity. This hypothesis imposes a specific empirical constraint on any future theory of quantum gravity: in its low-energy limit, it must reproduce the rule $\Phi = R + kF^2$ as the criterion for the possibility of space quanta self-organization. This means that testing the hypothesis through observational cosmology is simultaneously an indirect test of quantum gravity theories—a possibility that was previously considered practically inaccessible.

5.2. Additional Prediction: Magnetars as Laboratories

Magnetars are neutron stars with magnetic fields B ~ 10^(14)–10^(15) G [10]. Near their surface, F^2 reaches values comparable to the critical ones for testing the hypothesis. According to our model, in the immediate vicinity of a magnetar, the self-organization of quanta is destroyed, $\rho\Lambda = 0$; however, at some distance, where the field weakens below the threshold, self-organization becomes possible. This creates a sharp gradient in the effective energy density, which could manifest as anomalies in the orbital motion of objects near magnetars. This prediction is unique to our hypothesis and has no analogs in other models.

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6. Comparison with Existing Models

A comparison of the key properties of our hypothesis with the standard ΛCDM model and the main screening models is presented in the table below.

Table 1. Comparison of Dark Energy Models.

Feature	ΛCDM	Chameleon	Symmetron	This Hypothesis
Nature of DE	Constant Λ	Scalar field	Scalar field	**Self-organization of space quanta**
Environmental Dependence	None	Mass masking	Field hibernation	**Destruction of self-organization**
Explanation of the ~7 Gyr transition	None	None	None	**Yes (field threshold)**
DE in the Laboratory	>0, but small	Suppressed	Suppressed	**Strictly zero**
Role of Electromagnetism	None	None	None	**Yes (key role)**
Predictions for Magnetars	None	None	None	**Yes**
Link to Inflation	Separate mechanism	Separate mechanism	Separate mechanism	**Option A: Separate; Option B: Unified**

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7. Discussion and Open Questions

7.1. Microscopic Mechanism

The hypothesis does not specify exactly how fields destroy the self-organization of space quanta. This requires development within the framework of a quantum gravity theory.

A more detailed picture can be described as follows. Space quanta have a fundamental ability for self-organization: in the absence of external influences, they tend to align into an ordered structure, perceived macroscopically as a new volume of space-time. Gravitational and electromagnetic fields act as a destructive factor: they introduce fluctuations into the system sufficient to break up the forming structure. In this picture, fields do not "forbid" birth in a directive manner but make it thermodynamically impossible—much like how weak heating prevents a crystal from forming in a supercooled liquid. This explains why even fields that are relatively weak by Planckian standards can suppress the birth of space: the system is near a critical point, where small influences lead to macroscopic consequences.

Possible directions for a future theory:

- In Loop Quantum Gravity [3], the formation of new nodes in the spin network may depend on local curvature.
- In Causal Dynamical Triangulations, the rate of simplex formation could be regulated by the field background.
- In String Theory, a mechanism is possible where D-branes screen the formation of new geometry.

7.2. The Coupling Constant k

The relative contribution of gravity and electromagnetism to the destruction of self-organization is unknown. It is described by the coupling constant k from the destruction criterion equation: $\Phi = R + k \cdot F^2$.

- If k is much less than 1, gravity dominates. In this case, the hypothesis reduces to purely gravitational screening, where electromagnetic fields play no significant role.
- If k is much greater than 1, then even weak electromagnetic fields can effectively destroy self-organization.

Measuring the contrast of dark energy density in various environments (e.g., in voids, where there are no fields, and near magnetars, where there is a powerful magnetic field but gravity is not extreme) will allow for an experimental estimation of the value of k. It can be tentatively stated that k cannot be extremely large, otherwise DE would be suppressed even in the intergalactic medium, contradicting observations.

7.3. The Transition Steepness Parameter κ

The parameter κ (the Greek letter "kappa") describes how sharply the transition from destroyed self-organization to active self-organization occurs when crossing the critical threshold. It appears in the sigmoid function for the local dark energy density:

$\rho\Lambda(x) = \rho\Lambda 0 / [1 + \exp(-\kappa \cdot (\Phi crit - \Phi(x)))]$

- As κ tends to infinity, the sigmoid becomes a Heaviside step function—the transition is instantaneous.
- For small κ, the transition is very smooth, and dark energy begins to manifest weakly long before the formal threshold crossing.

Future data from the Euclid mission on baryon acoustic oscillations and the growth function of the large-scale structure of the Universe can constrain the parameter κ, showing how sharp the historical activation of dark energy was. This, in turn, will shed light on the microscopic nature of the phase transition.

7.4. Significance for Quantum Gravity

This hypothesis is, strictly speaking, phenomenological: it describes the macroscopic consequences of a microscopic mechanism whose nature is currently unknown. However, its value may lie precisely in this.

Historically, new fundamental theories often began not with equations but with phenomenological rules that explained observed anomalies. Planck's hypothesis of energy quantization (1900) began as an empirical formula explaining the blackbody radiation spectrum. Zwicky's dark matter hypothesis (1933) began as a statement of a discrepancy between the observed and calculated mass of galaxy clusters. In both cases, it was the necessity to explain an observational fact that led to the creation of full-fledged theories—quantum mechanics and modern particle physics.

The present work may play an analogous role for quantum gravity. The observational fact—the late activation of dark energy—requires a mechanism linking the self-organization of space with the field background. If this mechanism is confirmed, it will become an empirical constraint on any future theory of quantum gravity: it must reproduce the rule $\Phi = R + kF^2$ in the low-energy limit. This turns cosmological observations into a tool for testing quantum gravity theories—a possibility previously considered practically inaccessible.

Of course, this hypothesis leaves open a fundamental question: how can fields, many orders of magnitude weaker than the Planck scale, influence the self-organization of space-time quanta? An answer to this question is absent within the framework of existing physics. However, it is precisely here that the heuristic value of the hypothesis lies: it formulates a specific task for a future theory of quantum gravity—to explain the mechanism of amplifying the sensitivity of quantum foam to macroscopic fields. If such a mechanism is found, it will not only be a solution to the dark energy problem but also direct confirmation of new physics at the interface of gravity and quantum theory.

7.5. Effects Near Strong Sources

The behavior of DE near black holes is of particular interest. On the event horizon, R diverges, guaranteeing the total destruction of self-organization and $\rho\Lambda = 0$ inside the horizon. However, in the ergosphere of rotating black holes, regions may exist where the gravitational field is strong but the EM field is absent. This creates unique conditions for testing the ratio of the R and F^2 contributions.

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8. Conclusion

A new hypothesis has been proposed explaining the late onset of the accelerated expansion of the Universe through the mechanism of field-induced destruction of space quanta self-organization. The hypothesis:

1. Simultaneously solves the coincidence problem and the local invisibility problem of DE.
2. Does not contradict established physical theories (GR, QED, thermodynamics).
3. Offers concrete, falsifiable predictions testable by current and future observational facilities (Euclid, magnetar analysis).
4. Is consistent with inflationary cosmology, both in the standard variant (inflation as a separate process) and in a more radical one (a unified mechanism with inverted birth).
5. Differs from all existing screening models by including the electromagnetic field in the destruction criterion and predicting a strict zero DE in dense environments.

6. Links the activation moment of DE with the observed astrophysical picture of the end of the "cosmic noon" and the onset of deep void formation.
7. Proposes an empirical bridge between observational cosmology and quantum gravity theory, imposing constraints on the low-energy limit of any future theory.

We believe that this hypothesis opens a new direction at the intersection of quantum gravity and observational cosmology.

Main Results

- A mechanism for the field-induced destruction of space quanta self-organization is proposed as an explanation for the late onset of the accelerated expansion of the Universe.
- A destruction criterion is formulated: $\Phi = R + kF^2$, where R is the scalar curvature, F^2 is the electromagnetic field tensor, and k is a coupling constant.
- It is shown that the crossing of the critical threshold Φcrit about 7 billion years ago coincides with the end of the "cosmic noon" and the onset of deep void formation.
- An observable contrast in dark energy density between voids and galaxy clusters is predicted, as well as a strict zero dark energy density in laboratory conditions.
- The hypothesis imposes an empirical constraint on quantum gravity theories and offers a method for their indirect verification through cosmological observations.

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Here are the final sections of the English version of the article.

Acknowledgements

The author expresses gratitude for the productive discussions that helped refine and strengthen the formulations of this hypothesis, particularly regarding the shift from the concept of "collapse" of space to a more rigorous "field-induced destruction," and for assistance in analyzing the compatibility of the hypothesis with quantum electrodynamics and inflationary cosmology.

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Appendix A: Illustrative Graph of the Hypothesis

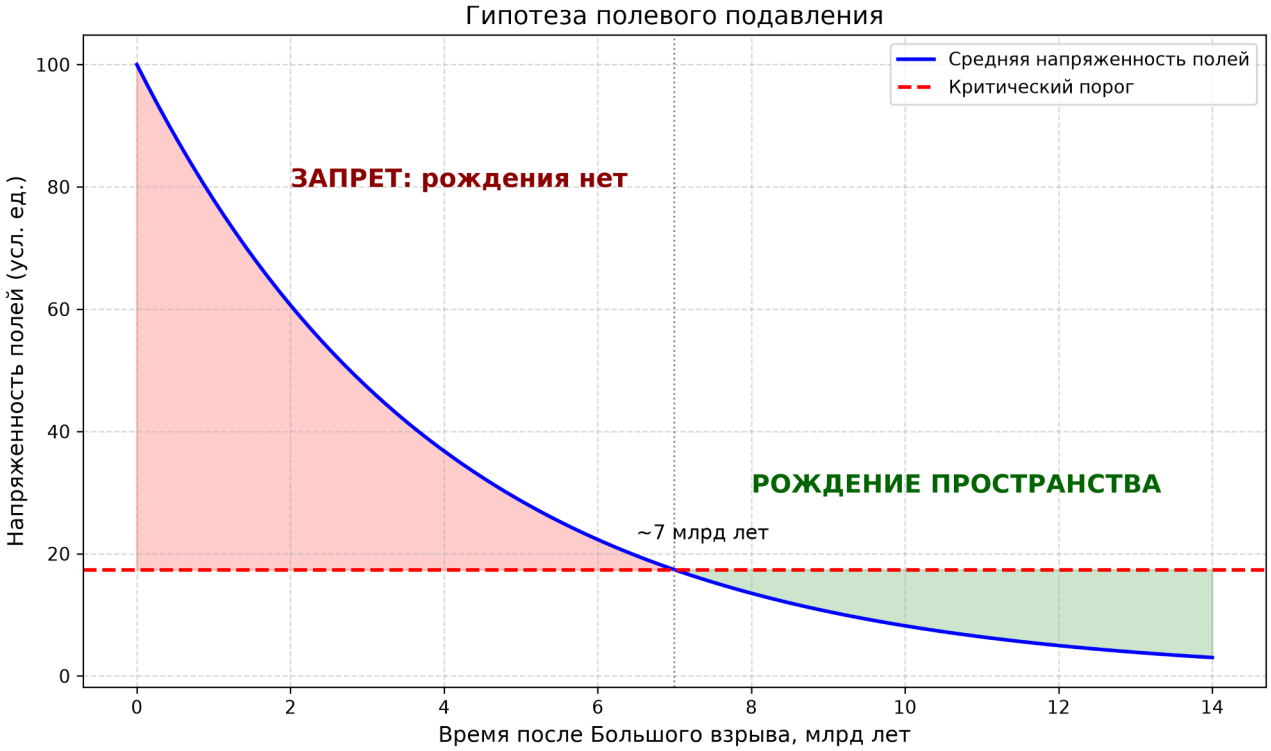

Fig. 1: Schematic illustration of the field destruction hypothesis. The X-axis plots time from the Big Bang (in billions of years), and the Y-axis plots the average field strength (in arbitrary units). The blue curve shows the exponential decline of the average field strength $\langle\Phi\rangle$ over time. The red dashed line is the critical threshold Φcrit.

- **Red zone** (left): The era of DESTRUCTION, $\langle\Phi\rangle > \Phi$crit. Self-organization of space quanta is impossible, and the effective density of dark energy is $\rho\Lambda = 0$.
- **Green zone** (right): The era of SELF-ORGANIZATION. $\langle\Phi\rangle < \Phi$crit, $\rho\Lambda = \rho\Lambda 0$, and accelerated expansion begins.
- The intersection point corresponds to an age of the Universe of ~7 billion years ($z \approx 0.7$).

Appendix B: Schematic of the Mechanism

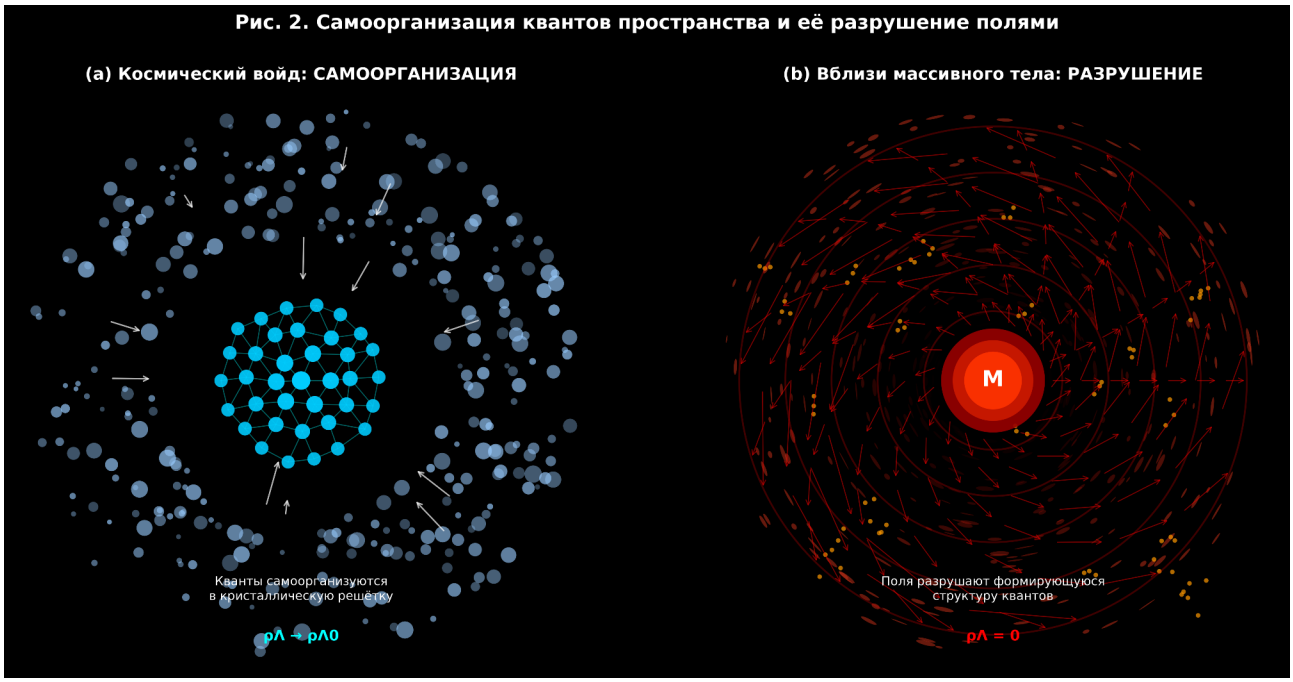

Fig. 2: Schematic of the mechanism of field-induced destruction of space quanta self-organization. (a) In cosmic voids, where fields are minimal, quanta are drawn to centers of crystallization and arrange themselves into an ordered lattice—new space is born. (b) Near massive bodies, strong gravitational and electromagnetic fields create turbulence that destroys the forming structure, rendering the birth of new space impossible.

Appendix C: Comparison of the Two Options for Linking with Inflation

Table 2. Two options for reconciliation with inflationary cosmology.

Feature	Option A (Standard)	Option B (Radical)
Nature of Inflation	Separate inflaton field	A unified mechanism with inversion
Link to Late Acceleration	Absent	Two regimes of the same fundamental process
Theoretical Complexity	Minimal	High (requires new physics)
Predictive Power	No new predictions for the early Universe	Predicts a connection with a new type of relic gravitational waves
Primary Risk	Does not explain inflation, but does not contradict it	Requires an inversion mechanism not yet mathematically described

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